Changes in Protected and Grazed Sagebrush-Grass in Eastern Oregon, 1937 to 1974

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Summary

Time was the most significant factor influencing brush and grass change inside and outside cattle exclosures over a 37-year period (1937-1974).

The 10 exclosures (2 ha) represent the big and low sagebrush (*A. tridentata* and *A. arbuscula*) bunchgrass vegetation of eastern Oregon and were established on the Squaw Butte Experiment Station as it was being developed in the drought years of the 1930s. Charts of permanent plots in 1937 were reevaluated into frequency estimates and the field plots monitored for specie frequency in 1960 and 1974. Frequency of bluebunch wheatgrass (*A. spicatum*), Idaho fescue (*F. idahoensis*), bottlebrush squirreltail (*S. hystrix*), Thurber's needlegrass (*S. thurberania*), and Sandberg bluegrass (*P. sandbergii*) increased or remained stable on both big and low sagebrush habitat type, except for the latter grass on the low sagebrush type.

Change in grass frequency outside the exclosures and subjected to grazing was not significantly different from that measured within the exclosures and protected from cattle grazing. Frequency of big and low sagebrush decreased inside and outside the exclosures over the 37-year period; however, the loss occurred primarily after 1960. The sagebrush reduction is believed to be the result of an infestation of the sagebrush defoliator moth (*Aroga w.*) which was prevelant throughout the Great Basin from 1962 to 1965 and present on the sagebrush at the Squaw Butte Station.

The lack of differential response by grasses between protected and grazed years in the early years can be attributed to 1) favorable moisture years after 1937, 2) change from early spring grazing by sheep (1920 to 1935) to spring-through-fall grazing by cattle, and 3) an overall lessening of grazing pressure. Herbaceous change in the latter years, despite the reduction in brush frequency, was small and reflects the dominating competitive force which sagebrush exerts on these communities and the tenacity with which it clings to this environment.

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The validity of grazing on natural resource lands by domestic livestock depends on sustained productivity and ecosystem stability. Management must rely on the scientific community to interpret current and past studies that have lingered through time but yet remain silent. In the last several decades, a number of such silent studies regarding the sagebrush-steppe ecosystem have been vocalized: Young (1958), Johnson (1969), Robertson (1971), Harniss and West (1973), Rice and Westoby (1978), Tueller and Tower (1979), Hughes (1980), and Holechek and Stephenson (1981). Results of those studies all suggest that some change has occurred. But the degree of change, direction of change, and the interpretive cause associated with the change are not always harmonious within or among the studies. Most of these studies have shown that sagebrush has changed little or increased whether protected or unprotected from grazing. The fact that complete harmony does not exist in the literature should not cause anxiety; variability is the major constancy of biological order. Success is achieved when the discord is recognized and interpreted.

This bulletin explores the vegetation change that occurred inside and outside 10, 2-hectare cattle exclosures constructed in 1937 on the Squaw Butte Experiment Station. The authors attempt to explain vegetation change between 1937 and 1974 in relation to pre-exclosure grazing history and concurrent grazing.

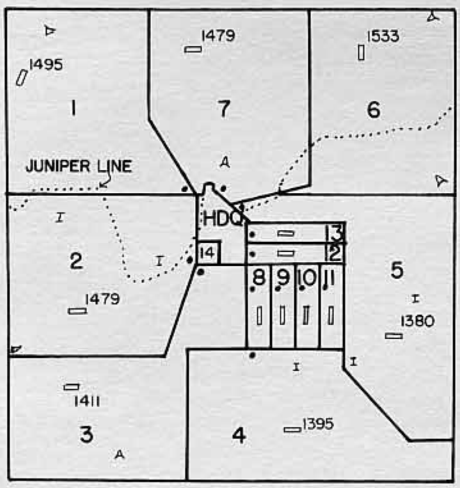

Figure 1. Squaw Butte Experiment Station (□ cattle exclosure, elevation in meters; water locations, • piped, ► reservoir, I cana flat pit).

The Squaw Butte Experiment Station

The station, within the sagebrush-bunchgrass type 64 kilometers west of Burns, Oregon, has an elevation ranging from 1,373 to 1,678 meters. The southern half of the 6,580-ha station (Figure 1) is undulating sagebrush-bunchgrass. The northern portion is associated with a juniper counterpart amid rimrocks, buttes, and elevated plateaus.

The vegetation is a shrub-steppe with some juniper (*Juniperus Occidentalis* subs *occidentalis*) overstory. Shrubs are primarily *Artemisia* and *Chrysothamus* and understory grasses are primarily bunchgrass. Cheatgrass (*Bromus tectorum*) is an important alien annual species. Heady (personal communication, 1983) suggests that it is now part of the climax. This is in part confirmed by Passey et al. (1982) who found it on 32 relict areas of the Intermountain sagebrush range.

The soils of the station are unclassified but most have been described by Eckert (1957). Most are loams or sandy-loams of rhyolitic or basalt origin underlaid with an indurated pan of silica at depths varying from 30.5 to 91.4 cm. In 1967, the vegetation and soils of the station were described and mapped under the direction of Dr. Charles Poulton.

Exclosure location and vegetation

Thirteen, 2-ha exclosures were constructed in 1936 (Figure 1, with elevation of each shown on the map). Seven were within large 810-ha range units and six were within smaller 65-ha pasture units. Exclosure location within the 65-ha units was evidently systematically located. The basis of selection of exclosure sites within the seven larger ranges is not recorded in the files.

Exclosure 1. On a steep, 30-degree northfacing slope, this exclosure is typed as occurring in three habitats. A mixture of mountain big (*A. tridentata vaseyana*), Wyoming (*A. tridentata wyomingensis*), and low (*A. arbuscula*) sagebrush was present in 1974 but was undifferentiated in 1937. The dominant grasses are bluebunch wheatgrass (*Agropryon spicatum*) and Idaho fescue (*Festuca idahoensis*) with a juniper overstory. In this study Exclosure 1 is grouped with Exclosure 7 because of similarity of herbaceous vegetation.

Exclosures 2 and 3. Both are dominated by Wyoming sagebrush and bluebunch wheatgrass. Exclosure 3 differs from all others because of its sandiness and has considerable amounts of green rabbitbrush.

Exclosure 6. This exclosure is at the highest elevation and supports mountain big sagebrush with an understory dominated by bluebunch wheatgrass and Idaho fescue and is within the juniper type but is relatively free of juniper.

Exclosure 7. A mixture of low, mountain big, and Wyoming sagebrush with a juniper overstory characterizes this site. The understory vegetation is bluebunch wheatgrass and Idaho fescue.

Exclosures 9-13. All are dominated by Wyoming sagebrush except Exclosure 11, which has green rabbitbrush (*C. viscidiflorus*) as a codominant. Thurber's needlegrass (*Stipa thurberiania*), Idaho fescue, and bluebunch wheatgrass codominate in Exclosure 11 and bluebunch wheatgrass and Idaho fescue are codominants in Exclosure 12 and 13.

Exclosures 4, 5, and 8. These three were excluded from this study because of research studies involving those areas in the field season of 1974 or previous treatment of those areas that may have altered the vegetation beyond that which would have occurred from grazing treatment alone.

Plot location

A single permanent plot, 6.1 × 6.1 m, was located within and outside each exclosure. As plots differ in their location inside and outside among locations, it is assumed that plots were not systematically placed. It is evident from the data that the plot locations were selected at random from some form of a grid base. Only in one of the 10 examined exclosures (Exclosure 1) was the vegetation difference between the inside and outside of the exclosure in 1936 of such magnitude that it weakened comparative analyses.

Water locations

There is no live water of sufficient volume to provide stockwater on the Squaw

Butte Station. Before establishing the Squaw Butte Station, ponded water from snow melt and "Cana" flats probably provided the only source of water for domestic stock and wildlife. This source of water would have rarely lasted beyond the first of July. During the 1936 to 1940 period, approximately 16 surface catchments were developed and two central wells bored to provide stock and domestic water. The location of these surface catchments and watering points from piped water are shown in Figure 1. Only a few of the surface reservoirs were capable of holding water into late summer. Before 1950, water was hauled on an extremely limited basis.

Beginning in 1950, trucked water increasingly became more of a management factor as the road system increased. Within a few years, 80 to 90 percent of all stockwater was trucked to portable water tanks and all ranges were uniformly grazed. Because of location and relation to water, grazing impacts on plots outside of exclosures in the period before water hauling were perhaps greatest for Exclosure 7, followed by 2, 3, and 1. After 1950, this difference diminished, except for that of Exclosure 1. Because the 65-ha pastures all had water piped to them, grazing use within each was not restricted to any great extent because of water.

Historic use

Before the early 1920s, the range area now within the station fence was a portion of a wild horse range. During the early 1920s and up to 1935, it was leased, and used as a sheep-lambing area. Detailed records of use before 1935 are not available. However, it is general knowledge that low economic return from these ranges was the reason for implementing research to improve the deteriorating rangeland in eastern Oregon. The station's range had been degraded, principally by sheep grazing, during March, April, and May.

Concurrent exclosure grazing use and management factors

The station's land was withdrawn in 1935 and there was no grazing in that year. Portions of the cow herd base were purchased in 1936, 1937, and 1938. In 1939, a deferred rotation vs season-long study began that continued for 10 years. Ranges 1, 6, and 7 comprised the rotation pastures and range 2 was the season-long pasture.

Initially, the station's research was to explore both cattle and sheep management. A band of sheep was purchased in 1936 and began grazing in 1937. However, because of complications in providing year-round feed, the sheep research terminated in mid-1939.

The records show that Range 5 was totally deferred from grazing through 1943. The specific use of Ranges 3 and 4, and the 6, 65-ha pastures before the mid-1940s was

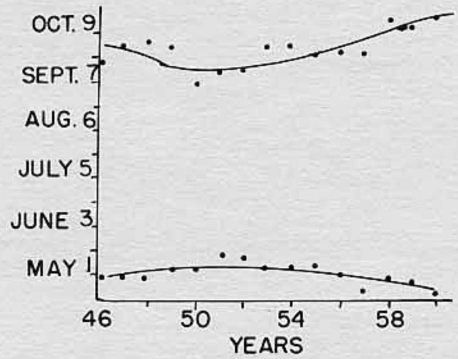

Figure 2. Beginning and ending dates of grazing on range at Squaw Butte.

not generally recorded in the files. However, portions of Range 3 were involved in many seeding trials during that early period; so it is unlikely that much grazing occurred in that pasture from 1936 to 1945.

It is known that up to the early 1950s grazing in Ranges 3, 4, and 5 and the 65-ha pastures was generally deferred until after larkspur (*Delphinimum megacarpum*) had flowered. This was done to reduce the incident of cattle loss from larkspur poisoning, a major problem on these degraded ranges.

In addition to the construction of buildings, roads, fences, and water developments by the Civilian Conservation Corps, a number of vegetation manipulations were also completed in those years that impact on this examination. Larkspur, death camas (*Zyadenus paniculatus*), and lupine (*Lupinus caudatus* and *L. wyethii*) were grubbed from Ranges 1, 6, 7, 8, 9, 10, 11, 12, and 13 during 1935 and 1936. The records state that an estimated 95 percent of these plants were removed. Yet, that grubbing of larkspur was successful only temporarily as indicated by the necessity to defer cattle grazing in the 160-ha pastures (Ranges 8-13) in the 1940s. In addition, all sagebrush from Range 14 and about 81 ha in the Headquarters area was removed by grubbing. It is evident from the records that grubbing of brush from a small portion of some exclosures did occur for comparing vegetation response. However, portions grubbed did not include the permanent plots considered herein.

Stocking of these ranges from 1938 to 1949 was based on range surveys conducted in 1938 and in 1944. However, despite the management practices and land use deferrals practiced during 1936 to 1949, the anticipated range improvement had not materialized. Thus, in 1949 a decision was made to redirect the research effort towards a more active program of range improvement research, thereby acknowledging the fact that management returns were too little and too slow in returning this range to greater productivity.

In 10 years (1949 to 1959), approximately 1,418 ha of chemical brush control were completed in Ranges 4 and 5 and approximately 324 ha of crested wheatgrass (*A. desertorum*) were seeded (Range 5 and Headquarters). Another 162 ha of crested wheatgrass were seeded in the 1960s (selected areas in Range 1, 2, and 3). The road system was increased, more fencing added, and watering by truck was intensified.

In addition to those improvements, the cow herd was culled intensively, the grazing season was shortened (Figure 2) on both ends, and total use of range forage diminished during the improvement period (Figure 3). These reductions in range use were offset by maintaining the cattle on the winter meadow unit longer and the use of fertilizer to increase the production of the meadow to meet the increased demand for hay and meadow grazing.

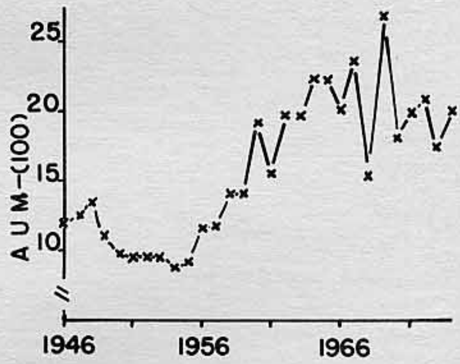

Figure 3. Total animal unit months of grazing at Squaw Butte, 1946 to 1974.

In 1966, the 6, 65-ha pastures were aerially treated with 2,4-D for brush control. Exclosure plots (inside and outside) of ranges 8, 10, and 13 were excluded from the control effort with 18.6 buffer strips. Exclosures in ranges 9, 11, and 12 were treated with 2,4-D.

Since the termination of the deferred rotation study in 1949, the grazing program has been one of applying good range management without a prescribed system of use, consistent with environmental and research concerns. Thus, in some years, some pastures were deferred and occasionally rested. The stocking rate and season of use were determined yearly for each pasture based on its record, production estimates, and program needs. However, because of early spring grazing needs, Range 4 and later Range 6 were systematically used for early turnout units during the late 1950s and 1960s, respectively. However, cattle were removed before May 15 which, in most years, provided good recovery and carry-over herbage for the following season.

The impact of this was such that by 1960 total range use had returned to pre-1950 levels, with range production increased such that good management principles could be applied and acceptable beef gain realized without subsequent range deterioration. Range use continued upward to the mid-1960s and since then has fluctuated around the 2,000 animal unit months level. Duration of grazing for 1960 to 1974 is not shown in Figure 2 but has varied from about April 15 to November 1.

Study period climate

Recording of daily precipitation and temperature began in 1937. The long-term average annual precipitation is about 30 cm, mostly snow or rain during the winter months, with about 25 percent received as rain in May and June. The average length of the frost-free period is 83 days (based on weather records of the Burns station (Gomm 1979)). Although the statistic is not too meaningful for defining growth activity of our native plants, it is indicative of the environment's harshness. Decadal precipitation means (Table 1) suggest that the area, for at least 20 years after the drought, received considerably more precipitation. A somewhat drier period began about 1968 and continued through the end of this study in 1974. Like other areas of the west, the range in crop-year precipitation extremes has been large. Precipitation amounts during the September through June period were below the first quartile precipitation level (12.8 cm) in 1939, 1950, 1954, 1955, 1959, 1962, 1966, 1968, and 1973. Of those, 1968 received the least precipitation (12.3 cm). Precipitation exceeded the third quartile precipitation level (30.7 cm) in 1941, 1943, 1948, 1953, 1956, 1957, 1958, 1963, and 1965. The highest precipitation amount (41.2 cm) was recorded in 1958.

Biotic incidents

During the 37-year period, only one incident of biotic infestation that may have influenced vegetation change is known. This range area, like much of the sagebrush range throughout the Great Basin, was host to an outbreak of the sagebrush defoliator moth (*Aroga websterii*) from 1962 to 1965. The intensity of infestation varied widely, but there were few hectares, if any, that were free of infestation.

Populations of rabbits and small rodents have varied over the years. In particular, rabbit population was high in the 1920s and 1930s but has been at relatively low levels except for the mid-1950s when high numbers were reached in 1955.

Methods

Plots inside and outside each exclosure were inventoried by a chart-quadrat method in 1937. In 1960, Tueller (1962) decided to utilize both frequency and density measurements to obtain information about plant composition and change. Thus, in 1960 and 1974, the field plots were divided into 100, 0.61 m^2 units from which density and frequency of each plant were determined. These results were then compared with density and frequency counts obtained from the original charts mapped in 1937. Basal area and/or stem location of each plant was charted in 1937 along with shrub cover outline. All rooted plants with more than one half of the base within the plot were recorded.

Determination of presence per 100 plots was used to obtain a frequency percentage. The data were analyzed as a split-plot in time with pasture locations and grazing treatments representing the whole plot. Frequency percentages were transformed to the Arcsin (percentage)½, as outlined in Steele and Torrie (1960). Zeros were handled as suggested. Greatest emphasis was placed on the grazing treatment × year interaction as a measure of differential vegetative response with time.

Not knowing the intent of the scientist who designed the study, the following assumptions were made: 1) plots outside exclosures represented the same habitat type as those inside the exclosure, 2) pasture locations and years were considered random and grazing treatments fixed effects, 3) all other assumptions of the analysis of variance were met. Tueller (1962) encountered more than 80 broadleaf species, mostly perennial, associated with these exclosures.

Because of low frequencies of some, tremendous year response by others, misidentification by examiners over years, and the elimination of other broadleaf succulents by grubbing in 1936 and 1937, it was our decision to confine the analysis to that of change in sagebrush, rabbitbrush, and the perennial grass species.

Table 1. Decadal means of cropyear precipitation (September to June, inclusive) (cm) at the Squaw Butte Experiment Range

Years	Precipitation
1928-1937[1]	17
1937-1947	28
1948-1957	28
1958-1967	26
1968-1974[2]	22

[1]Estimated from records of Lake (80 km W.) and Harney Branch Station (61 km E.).
[2]7-year mean.

Results

Frequency vs density

Although no attempt was made to make a direct comparison of the relative merits of frequency vs density to measure vegetation trends, it would appear that frequency would be the preferred method under the above circumstances. This is primarily because frequency measures can be taken more rapidly in the field. Of the 48 "F" values determined on main effects (pasture location, grazing treatments, years), a discrepancy between the two methods in the probability level at which differences were detected occurred in only four instances. In all instances, frequency measures detected differences at higher probability levels than density values. In only one instance would use of density vs frequency have changed the interpretation of an interaction mean. A similar conclusion was made by Hyder et al. (1963). Therefore, this paper will consider only frequency data, except where density would add clarity to the interpretation.

Artemisia Tridentata / Agropyron Spicatum Habitat Type

No difference in the average percentage frequency of the dominant grasses or brush species was found between plots inside vs outside of exclosures. The probability that such differences could occur by chance alone was always greater than 10 percent and in most cases was greater than 50 percent. Likewise, changes in percentage frequency of major species inside and outside exclosures (pasture location × grazing) were similar ($P > .10$ to $> .50$) between 1937 and 1974.

Large differences in percentage frequency of a given species were found among pastures, e.g., bluebunch wheatgrass, $P < .005$; Sandberg bluegrass, $P < .05$; bottlebrush squirreltail, $P < .05$, and green rabbitbrush $P < .025$. No differences ($P > .10$) in needlegrass or Idaho fescue were found among pastures.

Some of the most significant changes occurred over time (Figures 4 and 5). A significant difference ($P < .05$) in Sandberg bluegrass, needlegrass, bottlebrush squirreltail, Wyoming big sagebrush, and green rabbitbrush occurred among years. Sandberg bluegrass increased about 35 percent between 1937 and 1960 ($P < .05$) and remained at about 20 percent above 1937 values in 1974. Bottlebrush squirreltail and

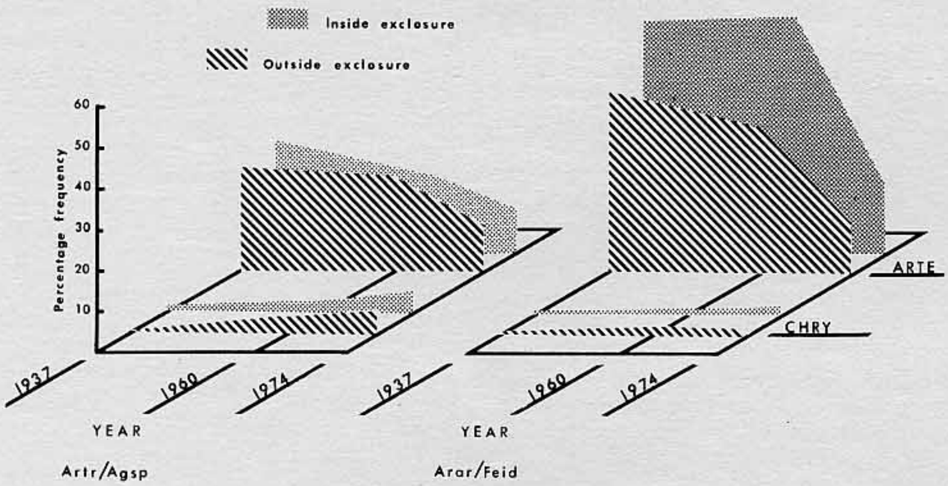

Figure 4. Percent frequency change of brush species inside and outside of exclosures on a big sagebrush-bluebunch wheatgrass (Artr/Agsp) habitat and on a low sagebrush-Idaho fescue (Arar/Feid) habitat at Squaw Butte, 1937 to 1974.

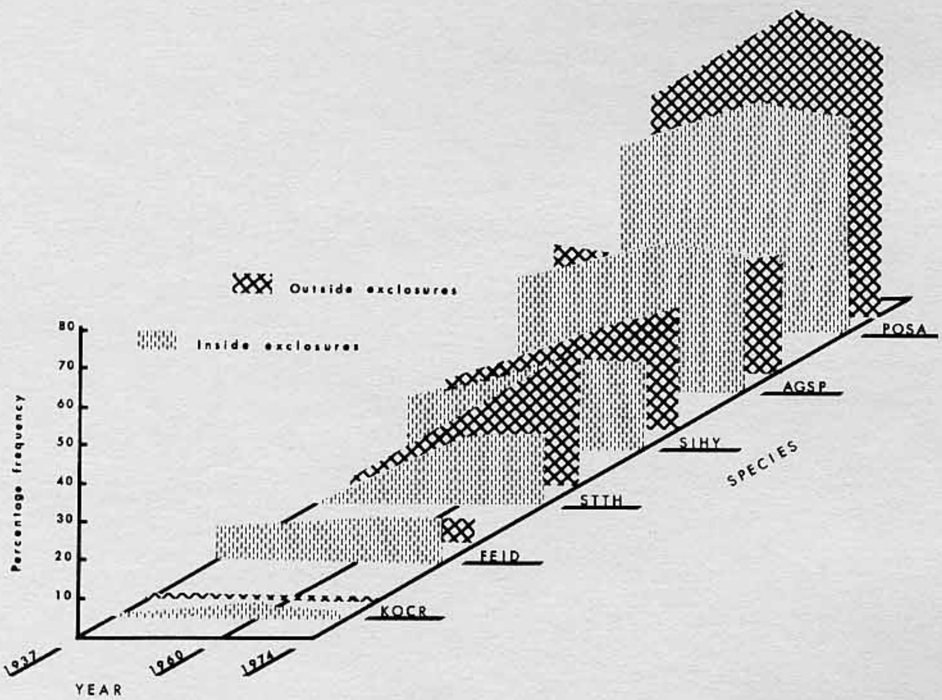

Figure 5. Percent frequency change of understory grasses inside and outside exclosures on a big sagebrush-bluebunch wheatgrass (Artr/Agsp) habitat at Squaw Butte, 1937 to 1974.

needlegrass increased from 13 percent to 28 percent and 1.4 percent to 28 percent, respectively, between 1937 and 1974.

Most (75 percent) of the increase in needlegrass occurred by 1960. Wyoming big sagebrush declined from 26 percent to 11 percent by 1960. Wyoming big sagebrush declined from 26 percent to 11 percent frequency while green rabbitbrush increased from 1 percent to 6 percent between 1937 and 1974.

Decline in sagebrush density during this same period reflected high mortality rates, i.e., 37 to 11 plants per 37 m^2, but little regeneration. Skeletons of many plants remain in the plots. Mortality rate between 1960 and 1974 was double that between 1937 and 1960. Green rabbitbrush steadily increased with time. However, most of this increase was attributable to only four of the eight pastures; the remaining four had low green rabbitbrush population, i.e., 74 vs 2.5 plants per 37 m^2, respectively. Stands of bluebunch wheatgrass, Idaho fescue, and Junegrass did not change significantly ($P > .10$) between 1937 and 1974 (Figure 5).

Artemisia Arbuscula / Festuca Idahoensis Habitat Type

Because of the low degree of freedom (1,1) associated with F values for estimation differences between pasture location and grazing treatment main effects, probability levels for detecting differences were > 50 percent for all species.

Sandberg bluegrass frequency declined from 91 percent to 76 percent ($P < .05$), and needlegrass, Junegrass, and Idaho fescue increased from 1 percent to 24 percent ($P < .005$), 20 percent to 56 percent ($P < .25$), and 38 percent to 70 percent ($P < .025$), respectively, between 1937 and 1974 (Figure 3). Bluebunch wheatgrass, bottlebrush squirreltail, sagebrush spp. (*A. tridentata* and *A. arbuscula*), and rabbitbrush spp. (*C. viscidiflorus* and *C. nauseosis*) frequency remained unchanged ($P > .10$) (Figures 4 and 6). A significant year × grazing interaction occurred only for Idaho fescue ($P < .05$). However, the year × grazing interaction based on density counts of Idaho fescue was not significant ($.10 < P < .25$).

Discussion of Statistical Results

Time was the dominant factor influencing change in percentage frequency of the species studied. Changes in five of the eight species studied were observed on both habitat types although the species involved and the direction of change varied.

Sandberg bluegrass increased in percentage frequency on the *A. arbuscula/F. idahoensis* (Arar/Feid) type. Although frequency appeared to follow a quadratic response on the Artr/Agsp type (Figure 5) with time ($1937 < 1960 > 1974$; $P < .05$), density steadily increased, i.e., 167, 253, and 268 plants/37.2 m^2 in 1937, 1960, and 1974, respectively. The cause of the differential response of Sandberg bluegrass between habitat types is unknown. Many compensating factors in the environment interact to cause change. It is most probable that the changes were the result of abiotic rather than biotic factors.

Percentage frequency varied widely among pastures (0.3 percent to 79 percent), but bluebunch wheatgrass remained as a stable entity of the plant composition over the 37-year period on both habitat types (Figures 5 and 6). Although large initial differences were found inside vs outside exclosures, subsequent measurements were similar. Some differences could be explained by the difficulty in defining a "bunch" of bluebunch wheatgrass. In some instances the plants tend to clone and boundaries become indistinct.

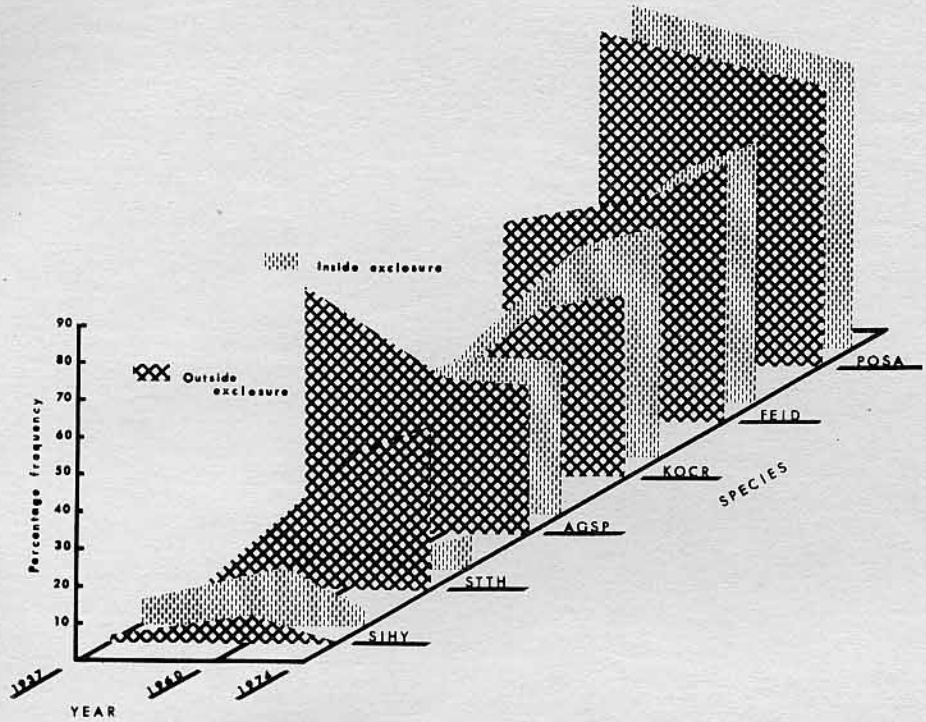

Figure 6. Percent frequency change of understory grasses on a low sagebrush-Idaho fescue (Arar/Feid) habitat at Squaw Butte, 1937 to 1974.

Bottlebrush squirreltail increased at all locations on the Artr/Agsp type between 1937 and 1974 (Figure 5). No clear trend was established on the Arar/Feid type (Figure 6). Since response was similar inside and outside exclosures, changes were attributed to abiotic factors.

Needlegrass increased dramatically between 1937 and 1974 on both habitat types inside and outside exclosures (Figures 5 and 6). No difference could be attributed to grazing. In 1937, 7 percent frequency was the highest recorded at any location. In 1974, the highest was 46 percent. Overall, needlegrass increased more than 25-fold in 37 years.

Frequency of Idaho fescue was low (< 10 percent) on the Artr/Agsp type and no trends were evident. However, on the Arar/Feid type, Idaho fescue steadily increased between 1937 and 1974 and the rate of increase was slightly greater on the protected areas. It is evident that the increase took place most rapidly in the pre-1960 era with little change resulting after that time. Sagebrush frequency changed little in the pre-1960 era but decreased in the post-1960 era.

In the words of a reviewer for an early draft of this manuscript, "It is unfortunate that so little information is learned from exclosure studies." It is easy to suggest that the inadequacy of 1) one plot/exclosure, 2) three examinations over a 37-year period, and 3) response measurements restricted to density or frequency do not allow for detail interpretation. However, it is possible, perhaps quite likely, that had the study been more intensive the primary outcomes would be no different than that obtained. The difference would be a stronger data base to support the conclusions drawn.

Thus, the authors accept the suggested outcomes of the data but, rather than discuss them directly, choose to attack the questions raised by them. In attacking those questions we will bring to bear upon them not only the data generated in this study but also the knowledge gained from other research conducted at Squaw Butte and elsewhere in the big sagebrush region. Such would be helpful in understanding the response of the vegetation to biotic and abiotic stimuli.

But it is necessary to have a better grasp of the range condition and its production when the first measurements were recorded in 1936 and 1937. The drought of the 1930s in eastern Oregon began in 1928 and did not break until 1938. The Experiment Station lands were set aside in 1935 and the records reveal no grazing in 1935 and about one month of use in the late fall of 1936. The first range survey of five of the large pastures in 1936 estimated acres per animal unit month ranged from 13.2 to 53.4. In 1938, a survey of those same pastures estimated the range from 6.9 to 27.1 acres/AUM. The difference, according to 1938 examiners, was because 1) inexperience of examiners in 1936 with the square-foot density method, 2) the non-standardization of the method itself, i.e., the forage acre factors were just beginning to be developed, 3) strong vegetation response from increased precipitation, and 4) grazing pressure relief in 1935, 1936, and 1937. The high acre/AUM requirement in both the 1936 and 1937 survey was that estimated for Range 5, a range that was not grazed until 1943. In 1944, the range survey estimated the acres/AUM from 6.0 to 7.6; however, this was judged to be too high by examiners after the 1948 survey.

The period between 1937 and 1944 was one of relatively high precipitation and with the cow herd still in a building program the total AUM's on this range probably did not exceed 1,000 AUM's before the early 1940s. As the cow herd increased above 1,000 AUM's in the mid-1940s (Figure 3), it became clear that the forage supply was not meeting the demand and that the improvement in production originally anticipated to have resulted from range and herd management was not going to be realized. Thus, in 1949, significant changes in the research, cattle, and range management programs were initiated.

Although the productional increases anticipated did not occur, there is evidence throughout the early reports of positive changes in frequency and densities of the bunchgrass. It is inferred that there was a reasonable amount of grass remnants that survived the extended drought and that, particularly its duration, created an unrealness in the minds of lay people as well as the professionals, who ultimately recognized the range to be in a poorer state of condition than what it really was, and perhaps also underestimated its resilience and ability to respond to increased precipitation.

It will also be helpful if we can first challenge the question, "How well does the 1960 data represent the peak in change?" We are seriously limited here because before 1948 the intensity of the effort for proving the square-foot density technique as an adjudication tool almost excluded measurements of response such as shrub cover or production per land unit. However, in 1938, 20, 1.5×1.5 m plots were cleared of sagebrush and in 1939, the grass production on those plots averaged 409 as compared with 148 kg/ha on the same number of plots with sagebrush remaining (Squaw Butte file data). The increased production of 276 percent is similar to that which we might expect today from a comparable production base. Forage yield was reported in 1941 to be 362, 258, 243, 253 kg/ha for ranges 1, 2, 6, and 7, respectively. Those yields, clipped from a good number of plots, were used to build a relation with the square foot density range survey data from which 1938 production was estimated to be 320, 156, 290, and 286 kg/ha for the same ranges, respectively (Squaw Butte file data). Those yields are not particularly different from those reported by Hyder and Sneva (1956), estimating yields in Range 14 to range from 133 to 246 kg/ha from 1951 to 1954 and classifying the range to be in fair condition. Likewise, Hedrick et al. (1966) reported yields of fair range control plots in Range 8 to be 249, 136, and 63 kg/ha for 1953, 1954, and 1955, respectively. The last year included a strong drought period.

Brush cover estimates in the early years are lacking. Brush cover estimates by Sneva (1979) of the charts plotted in 1937 estimated cover to be about 20 percent by line intercept. The frequency data (Figure 4) suggest little or no change up to 1960. Sagebrush crown cover averaged 18.7 percent in 1953 (file data) before treatment of plots (data were subsequently reported by Hedrick et al. in 1966). Range 14, initially grubbed of sagebrush in 1936 and with grazing deferred since 1935, by 1951 again had dominated the 16.2-ha pasture as evidenced by Hyder and Sneva's (1956) crown cover estimates ranging from 18.1 to 21.1 percent. Redomination by sagebrush of the Headquarters area (where sagebrush had been grubbed) also had taken place by 1950 and, in 1951, it was plowed and seeded to crested wheatgrass. It is inferred from this that percent cover of big sagebrush in the initial years of this study approximated that in the early 1950s.

The only significant decline of sagebrush during this period was believed associated with the infestation of *Aroga websterii* (sagebrush webworm or sagebrush defoliator moth) that occurred over a large interstate area, beginning about 1962 and continuing until 1966. At Squaw Butte, it was present almost everywhere but the intensity varied widely. Density measurements in 1963 and 1967 in Range 14 indicate that in that location a reduction of mature plants from 18.2 to 15.1 per 18.6 m^2 resulted, a decline of about 17 percent. There is another explanation for the decline of sagebrush. The decline may have resulted because of decadence of the stand, with the older brush plants not being replaced by young plants.

The analyses of Tueller (1962) do indicate some differences occurring in rates of grass species as they responded to the increased precipitation and to grazing, or the lack of it. It is also clear from the 1974 data that these responses had diminished. Hedrick et al. (1966) did not measure a significant shift in plant composition of untreated plots in fair condition 1953 to 1963 (i.e., that is, he did not report such a shift, if such was evident). Range 14 has been monitored yearly since 1952 for plant composition and has not particularly altered its bunchgrass composition except for that occurring in the immediate years after brush control in 1952.

From the foregoing the authors infer 1) that the response of the herbaceous level peaked earlier, perhaps as early as 1950, and 2) that sagebrush was not significantly influenced until the webworm infestation of 1963. Thus, a more realistic appraisal of changes in plant frequency is presented in Figure 7 based upon those inferences.

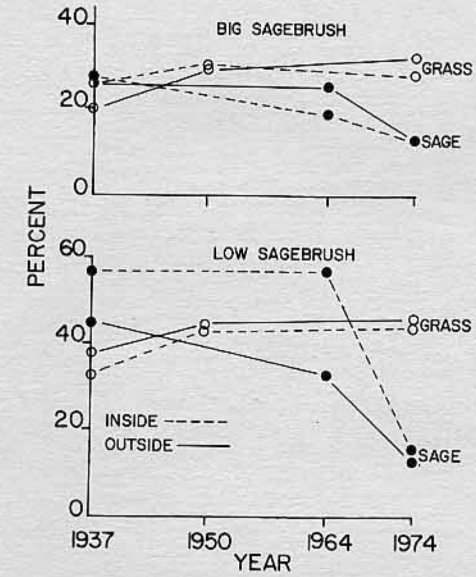

Figure 7. Most likely trend deflection points of mean grass and brush frequency inside and outside of exclosure at Squaw Butte, 1937 and 1974.

If Figure 7 can be accepted as such, perhaps we can attack the question, "Why didn't grazing from 1937 to 1950 have a stronger negative impact on the bunchgrasses?" We have already provided most of the answer. First, the strong response of all vegetation is a response to a much more favorable level of precipitation. In the 10 years after 1937, the mean crop year precipitation increase was 165 percent of the 10-year mean surrounding and including the drought years. This had to be a significant event for all vegetation of these rangelands. Secondly, the grazing had shifted from sheep to cattle use. The season of grazing had changed from late winter-early spring use to a spring-summer-fall use, and grazing pressure (even though we don't really have a pre-1936 measure) was probably reduced considerably. The best estimate of forage utilization during the 1937 to 1948 period is derived from the rotation vs season-long grazing data which suggest a mean forage use of about 58 percent.

That improper grazing can effect change in this vegetational type is answered from the deferred rotation vs season-long grazing study in 1939 which involved Ranges 1, 2, 6, and 7 and was terminated in 1948 (Hyder and Sawyer 1951). Bluebunch wheatgrass decreased in frequency outside exclosures in Ranges 1 and 7 yet increased inside the exclosures. It is this decrease in bluebunch wheatgrass that is primarily responsible for the differences in trend shown in Figure 6. Hyder and Sawyer (loc cit) attribute those declines to the heavy, early spring grazing pressure associated with the deferred rotation system which consisted of a three-pasture system with pastures grazed two years consecutively within a time period. This explanation is not without its contradictions. Range 6, the third unit of the rotation pastures, did not show a similar response; however, it is possible that year sequence interacted climatologically, which favored this pasture. Also, Range 6 has half of its range in southfacing slopes and level topography that in early spring would tend to draw the cattle away from the top where the exclosure is located. That this early spring grazing pressure was the primary cause of bluebunch decline in those pastures is further supported by the reversal of those trends outside the exclosure in the subsequent time period after the study was terminated and the concentrated, heavy spring use no longer applied to these ranges.

The next question then raised is, "Why, in the post-1950 era, didn't grazing influence the grass component more strongly?" A large part of the answer lies in the changes in range improvements and cattle management practices implemented beginning in the early 1950s.

First, a reduction of AUM's on range (Figure 3) occurred from 1949 to 1955. This reduction was structured primarily to delay turnout onto the native grasses (Figure 2) but also to lighten the total grazing pressure. Much of the reduced AUM's on range was absorbed on the winter meadow unit by increasing its production with fertilizer. However, the cow herd was heavily culled (a primary objective of the pre-1950 cattle program was to gain information on lifetime productivity of range cows); thus, by the late 1940s the herd had many very old, inefficient cows. The crested wheatgrass seedings initiated in the eary 1950s and the brush control with 2,4-D in the mid-1950s did much to alleviate the limited spring and summer forage supply.

A utilization survey in 1949 clearly showed the inefficiency of the centrally located water system and limited surface stockwater catchments to effectively harvest the station's forage. A water-hauling program was initiated in the early 1950s, all surface water supplies were fenced for control, and, by 1960, with use of movable stockwater tanks and developed truck trails, all forage grown was potentially within 0.4 to 0.8 km of controlled water.

The above range improvements, herd, and meadow management practices resulted in greater opportunities to protect the native ranges from the detrimental grazing in the spring period and provide for more uniform utilization throughout all ranges. Total AUM's grazing in 1960 were more than in 1940. Because of the management and improvements applied, turnout date onto the range was advanced in the spring and animals remained on the range later in the fall.

Even with crested wheatgrass pastures, an inadequate amount of new growth forage was available during April and May. During those months we utilized carry-over forage of native grasses in Ranges 6 and 4. This early spring use should not be confused with that applied in the rotation study. Movement of the cattle off these ranges by mid-May onto the crested wheatgrass, in all but the extreme drought years, has allowed for near full recovery of the native grasses and the forage carried over for the subsequent season. Under this type of use we have not visually observed range deterioration nor is there evidence of such a decline in the 1974 measurements of those pastures.

Although changes in range management and significant range improvements have impacted the grazed areas outside of exclosures, this study shows that moderate grazing applied in a conscientious range management program did not significantly alter the composition of native range forage over a 25-year period. Furthermore, productive capacity of the range increased.

It should also be clear that the management changes and range improvements in the post-1950 era have not influenced the vegetation inside the enclosures. Thus, the following question is pertinent, "Why didn't the rate-of-change associated with the bunchgrasses in the pre-1950 era continue into the subsequent years?" The authors will provide two answers for thought. First, herbaceous change climaxed by about 1950. If so, then change since would be that associated with yearly fluctuations of biotic and climatic events without, assumably, a distinct trend. The suggestion that the vegetation stands are near climax, for most, would be unpalatable for there is far too much sagebrush present if we accept the classical concept of the sagebrush-bunchgrass climax community to be that of "bunchgrasses with a dispersed community of sagebrush." Examples of such in the Intermountain Great Basin area are not overwhelming.

The remaining alternative is that the dominant competitive force within the exclosures (as well as outside) is limiting any further response by the herbaceous level. The volumes of literature for the sagebrush-bunchgrass ecosystem relating the suppression of the herbaceous layer or the release of it with the increase or decrease of the associated sagebrush stands are, perhaps, unsurpassed by other topics. The tenacity of sagebrush to persist and its aggressiveness to recover within its natural boundaries are truly amazing. In Range 14,

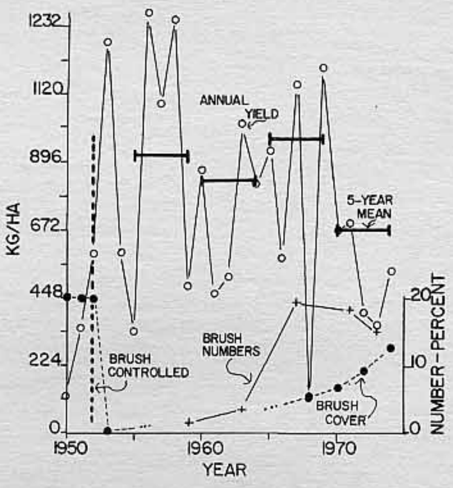

Figure 8. Annual herbaceous yield, sagebrush density (no/18.6 m²), sagebrush cover (%) before and after brush control in 1952. Five-year mean herbaceous yield adjusted for precipitation differences, Sneva and Hyder (1962).

deferred to grazing since 1935 and with sagebrush totally grubbed in that year, it regained total dominance of the community within approximately 15 years. Reduced again to almost nothing in 1952, it again is suppressing the herbaceous layer (Figure 8). Elsewhere on the station ranges it has maintained itself over a period of about 40 years with little or no outward appearance of change.

This alternative appears the most likely response to the question; however, its acceptance does not rule out the concept that a climax has been reached—it just evades answering the question as to where the community is on the ecological scale. This conclusion is not particularly different from that set forth by Pechanec et al. (1965), "Without removal of sagebrush only slight improvement in forage and yield can be expected on many ranges even after good grazing management has been practiced for 15 to 30 years."

If sagebrush is the dominant force influencing herbaceous change, we must consider the following questions: Why hasn't sagebrush been impacted either by rest or by grazing over these years? Why, after the reduction of sagebrush by the defoliation moth or by the 2,4-D spraying of Ranges 8-13 in 1966 did not a significant herbage response occur?

Suppression of sagebrush by grazing has been documented in two locations: the Dubois Experiment Station in Idaho (Laycock 1961 and 1967) and the Benmore Experimental Range in Utah (Frischknecht and Harris 1973). Both studies report results of fall grazing by sheep on *A. tripartita* in Idaho and *A. tridentata* in Utah. The pros and cons of the Idaho results have been further discussed by Wright (1969) and West et al. (1979). There is, however, no documentation of sagebrush suppression by cattle grazing. However, it is possible that grazing by cattle has had a stimulatory effect on the sagebrush stand through the breaking off of branches and soil disturbance interacting with seed dispersal and seed coverage.

Descriptions of sagebrush stands on the Squaw Butte Station in the mid-1930s are lacking. There is a similar dearth of information about other sagebrush stands in the western United States. Most often we are left with a descriptive "even-aged stand" or "a stand of mature brush evenly spaced" or "a 30 to 40-year-old stand of even size." The exceptions relate to returning stands after disturbances or rehabilitation where the aggressiveness, denseness, and age again are referred to in general terms. West et al. (1979) infer from a demographic study of sagebrush-grass communities in southern Idaho that these even-sized sage communities are, in fact, uneven aged. This supports the hypothesis of infrequently spaced climatic events conducive to the establishment and survival of big sagebrush. Sturges (1975) suggests a stand life of decades, "Individual big sagebrush plants commonly live for 50 to 75 years." Blaisdell (1953), commenting on the sagebrush range of southeastern Idaho, described the plants as even-aged stands of 30 to 40 years with individuals exceeding 100 years.

Adams (1975), in a study of juniper and shrub populations in Oregon, reported the mean age of sagebrush stands to be 20 years with 38 years the age of the oldest live plant but the age of dead plants ranged up to 66 years. It is somewhat difficult to transfer Adams' findings to the sagebrush system because his study was conducted in a site dominated by juniper with sagebrush cover estimated at less than 2 percent. However, he does show a strong reduction in sagebrush cover in the 1961-1970 period which may be associated with *Aroga w.* infestation. Thus, a review of the literature does not really help us to understand the kind of big sagebrush stands that existed 40 to 50 years ago. At best they might be described as "an abundance of even-sized, mature plants of uneven age."

The literature does inform us of several significant aspects of this sagebrush community. This community is essentially "closed" to new additions of sagebrush. Johnson (1958) in Wyoming concluded, "Sagebrush seedlings were practically non-existent on areas protected from grazing." Young and Evans (1974), studying the population dynamics of green rabbitbrush in disturbed big sagebrush communities, concluded, "When these communities are not disturbed..., no shrub seedlings are established." In Idaho, Tisdale et al. (1969) reported brush cover increases without accompanying increases in plant numbers on deteriorated rangeland—the inference being that little or no brush establishment was occurring in the existing stand. On a fair condition range in eastern Oregon, Hedrick et al. (1966) found that brush cover increased from 1 to 11 percent in the 8 years after sagebrush reduction by mechanical means with no significant increase in brush density.

In Range 14 at the Squaw Butte Station, median numbers of sagebrush less than 15 cm tall from 1959 to 1981 were 1.5 plants per 19 m^2 for the same time period, a rather low replenishment rate (unpublished file data). Thus, the inference drawn is that the stands of sagebrush in 1974 are basically the same plants existing in 1937 but are now considerably older.

However, despite that aging process, the competitive force sagebrush exerts has diminished very little and its capacity to respond still exists. The extent to which the herbaceous understory responds when sagebrush is totally or substantially removed or killed is almost ancient history. It needs no documentation. But, when a sagebrush stand is partially reduced either by numbers or in crown cover, there is also a strong response by the sagebrush itself such that in many instances it is more rapid and more competitive than that of the understory. Rapid response of sagebrush to partial opening was reported by Robertson and Pearse as early as 1945. Cook and Stoddart (1959) reported that by the third year, increased growth of the unclipped side of a sagebrush plant about compensated for the loss of the other one-half of the plant. Hull and Klomp (1974) reported a doubling of canopy cover and weight of remaining sagebrush in Idaho in a 5-year period after a 75 percent reduction of sagebrush. They concluded that the last 25 percent of sagebrush killed resulted in the greater proportion of the herbaceous release. This is consistent with much of the chemical-spray release research which suggests that 75 percent or more of the sagebrush needs to be controlled to achieve economic return. In 1947, Robertson concluded, "...brush (sagebrush) eradication will increase forage production, measure for measure."

Rittenhouse and Sneva (1976) and Cook (1958) reported a linear relation of crested wheatgrass (*Agropyron* spp.) herbage production suppression with increasing sagebrush cover. This differs slighty from Hull and Klomp (1974) which is suggestive of a curvilinear relation. The difference may be because of the manner of studies. Idaho researchers created the sagebrush release patterns from established stands, whereas the Utah and Oregon research examined productions on naturally developed stands of different sagebrush densities or cover. In Range 14, a reduced proportion of the native herbaceous plants is shown associated with a brush cover index of about one-half of the potential cover (Figure 8). In Idaho, Tisdale's (1969) data showed strong herbaceous response only after more than 50 percent of the sagebrush cover was removed. Johnson's (1969) data in Wyoming also suggest that production increases of associated grasses were nullified before sagebrush cover on treated areas returned to pretreatment or control levels. Harness and Murray (1973) summarized 30 years of change in the sagebrush range in Idaho and suggested, "Sagebrush control measures should be applied before the community climax..." inferring that sagebrush dominance of the community occurs early in the life cycle of a sagebrush-grass community. Thus, the reductions, believed caused by the defoliation and seen both inside and outside of exclosures at Squaw Butte were perhaps of insufficient magnitude to effect a herbaceous understory release because of the natural rapid response of sagebrush.

The lack of a productional response to spraying the 6, 65-ha pastures in 1966, an extreme year with poor results, also is explained because of stimulatory effects on the remaining sagebrush and if grass response occurred it was nullified by the time of the 1974 examination.

Conclusions

The findings of this exclosure study, extending over a period of 37 years, are not particularly different from those arising out of other exclosure studies elsewhere in the Intermountain sagebrush range. With strong precipitation increases after the drought and cattle grazing at moderate levels of forage utilization, positive changes in herbaceous species occurred both inside and outside the exclosure. Changes in brush frequency were similarly unaffected by protection or grazing but a reduction in brush frequency after 1960 measurements is believed caused by an infestation of webworm (*Aroga w.*). The level of brush frequency inside and outside the exclosures in 1974 is the primary competitive force suppressing herbaceous performance. Real (in the practical sense) increases in the herbaceous production will come only from real reductions in brush. Hindsight suggests that such brush reductions do not result quickly from protection.

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